LANDPRO: LANDSCAPE DYNAMICS PROGRAM IN SUPPORT OF NATURAL AND CULTURAL RESOURCES MANAGEMENT AND RANGE MAINTENANCE

T. F. Bullard* and E. V. McDonald
Desert Research Institute
Reno, NV 89512

ABSTRACT

LanDPro, the Landscape Dynamics Support Program, is being developed at the Desert Research Institute to support sustained mission capability and military readiness, and to help land managers achieve maximum use of resources available for training land maintenance. During the past several decades, the science of geomorphology and soils has advanced to the point of demonstrating unique and predictable relationships between temporal and spatial variation in landscape components and soils, hydrology, vegetation, geology, and prehistoric cultural resources. Recent research on military lands has added to our knowledge of individual soil-geomorphic processes that control landscape-vegetation relations. In turn, the geology, geomorphology, soils, and hydrology are being integrated into models designed to support the military mission. LanDPro serves as a seed for advancing integrated GIS-based land-management tools applicable to military installations around the United States. Goals of LanDPro are to support scientific development of new methods and models leading to better understanding in three focus areas: natural resources, cultural resources, and range management.

1. INTRODUCTION

Successful military training to meet readiness and battlefield preparation requires large areas of landscape representative of in-theater battlefield environments. DoD administers military installations, training lands, and ranges around the United States; nearly 70% are located in arid to semiarid environments, which are current strategic sites for military operations. To meet goals of maintaining and sustaining safe, realistic military training environments while maximizing use for active training, DoD spends upwards of $100 million annually on land management, training impact mitigation, and range operations including inventory and management of natural and cultural resources as required by the National Historic Preservation Act (1966) and the Sikes Act Improvement Amendments (DoD Authorization Act, FY 1998). Many of these efforts are primarily focused or conducted using single-discipline approaches (e.g., biology, archeology, GIS) and commonly lack scientific integration—especially with regard to soil science, geomorphology, and hydrology. This is not to say that current efforts and approaches are inadequate, rather that integrating the emerging scientific knowledge on surface processes into management strategies and activities often lags behind the rapid pace of scientific information being supplied.

During the past several decades, the science of geomorphology and soils has advanced to the point of demonstrating unique and predictable relationships between temporal and spatial variation in landscape components and soils, hydrology, vegetation, geology, and prehistoric cultural resources (e.g., Birkeland, 1999; Bull, 1991). Recent research on military lands has added to our knowledge of individual soil-geomorphic processes controlling landscape-vegetation relations and the geology, geomorphology, soils, and hydrology. These advancements are particularly important because most DoD installations in the western U.S. contain complex mosaics of landscapes and landscape components whose histories reflect climate, lithology, depositional and erosional processes, soil formation, and associated biologic communities. This underscores the importance of integrating the geology and geomorphic processes into models that will support the military mission. LanDPro serves as a seed for projects that can help to advance integrated GIS-based land-management tools applicable to military installations around the U.S. Goals of LanDPro are to support scientific development of new methods and models leading to better understanding in three focus areas: natural resources management, cultural resources management, and range management. The following sections describe these focus areas and the thrust of LanDPro.

2. FOCUS AREAS

The Landscape Dynamics Support Program (LanDPro) is designed to undertake new research and integrate that with existing landscape studies to advance our knowledge of geomorphic controls operating on landscape systems as they relate to cultural resources management, threatened and endangered species habitat, and landscape erosion. This overarching goal includes undertaking research to (1) understand landscape dynamics and evolution to better anticipate endangered species habitat and habitat responses to natural and

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anthropogenic disturbance; (2) design methods enabling archeological site prediction to increase efficiency of cultural resource inventorying methods; and (3) develop geomorphic methods and tools that will provide land managers with the means to predict training area sensitivity to disturbance and better anticipate future geomorphic responses to climate change as well as anthropogenic disturbance. LanDPro builds upon and integrates recently completed DRI projects on soil, geomorphology, hydrogeology, and cultural resources on DoD installations and attempts to improve the robustness and universality of existing tools in support of enhancing land stewardship.

2.1 Natural Resources Management

Mitigating impacts to threatened and endangered species is both costly and time consuming and can severely affect training activities. LanDPro research has the objective of developing a land management tool that can integrate the natural terrain–including geologic, geomorphic, soil, and hydrology characteristics–to assess habitat stressors present in the natural environment. To accomplish this objective, it is necessary to acquire a better understanding of the environmental factors that dictate the distribution and health of threatened and endangered species found on many military installations, such as landscape dynamics, soil, hydrologic, and geomorphic controls on habitat structure of threatened and endangered species and responses to disturbance. Studies have demonstrated the linkage between floral and faunal habitat and surface processes (e.g., Wierenga et al., 1987; McAuliffe, 1994; Smith et al., 1995; McAuliffe and McDonald, 1995; Hamerlynck et al., 2002; McDonald, 2003). Recent studies undertaken to relate species habitat to the landscape (and associated soils and fragmentation or destruction of habitat by training) rarely take into consideration how the distribution of landscape features, geomorphic processes controlling erosion and deposition, and the soil environment influence distribution or richness of species habitat structure (e.g., Kondolf and Larson, 1995; Poff et al., 2006; Monger and Bestelmeyer, 2006; Peters et al., 2006; Shafer et al., 2007). Geomorphic and soil processes operating on the landscape can be interrupted, changed, or redirected to different parts of the landscape following disturbance from training activities. The altered spatial distribution of geomorphic processes, soil characteristics, and soil hydrology following disturbance are capable of having profound effects on species habitats situated in high-traffic training areas.

2.2 Cultural Resources Management

Understanding the geomorphic controls on the distribution of cultural resources is leading to advances in strategic approaches to inventory surveys. As military installations acquire land to expand training and testing areas or develop buffer zones around the installations, the newly acquired terrain requires cultural resource surveys, evaluations, and mitigation measures to comply with Federal and State laws prior to use of the property. Currently, available tools and methods for large scale conventional pedestrian archeological methods are time and labor intensive and struggle to meet the expedited schedule for training area clearances and land acquisition. One solution for accelerating the compliance process of archeological identification and evaluation is to develop a model capable of predicting favorable locations of archeological sites and characterize the potential for site preservation, site burial, or both. This type of model, which requires incorporation of key geomorphic variables to determine how evolution of the land surface has contributed to the distribution of cultural features (e.g., McDonald et al., 2004a), can be used to characterize favorable locales for archeological site potential and to rank areas for cultural resources investigation to maximize fiscal resources and ensure timely compliance for acquisition and future use.

2.3 Range Management

Understanding the linkages between soil hydrology, soil geomorphology, and landscape evolution and the complex controls on erosion resulting from natural (such as extreme climate events) and human-induced disturbance on training lands is crucial in supporting management of environmental degradation. This focus area strives to advance and apply scientific knowledge to address training area degradation and enhance practices leading to training area sustainability. Military land damaged during training operations impacts nearly all facets of battlefield preparation. For example, fluvial erosion and deposition create mobility hazards, obstacles and barriers to transportation, and dust emitters, which can affect air and ground visibility, mechanical operation of vehicles, weapon function, communications, and human health. DRI has been involved in landscape research activities at several DoD installations in the arid southwestern U.S. and coastal semiarid environments investigating the role of soil-geomorphic and soil-hydrologic characteristics as they relate to landscape dynamics and military training. Recent DRI research in the southern California coastal region has identified discrete landscape responses to apparent climate change events (McDonald and Bullard, 2007, 2008a,b). This type of information can be used to anticipate potential changes in training lands under altered climate regimes. The next step will be to develop models capable of integrating geomorphology, soils, and hydrology to designate areas vulnerable to surface disturbance and anticipate those areas that could present potential safety concerns or sustainability issues related to training.

3. APPROACH

LanDPro is focusing research efforts on military installations located in three principal physiographic settings: coastal, low interior hot deserts, and semiarid high desert, which correspond to marine, tropical-subtropical deserts, and Mediterranean divisions of the Bailey ecoregions of the United States (Bailey, 1996) (Fig. 1). Other DoD funded studies have utilized Bailey's ecological framework to determine the general resiliency of training land to disturbance by tracked vehicle maneuvers (Doe et al., 2000). The three ecoregions where we are targeting research in key topical areas include regions categorized as low (tropical/subtropical and temperate desert), low-moderate (Mediterranean), and high (marine) resiliency.

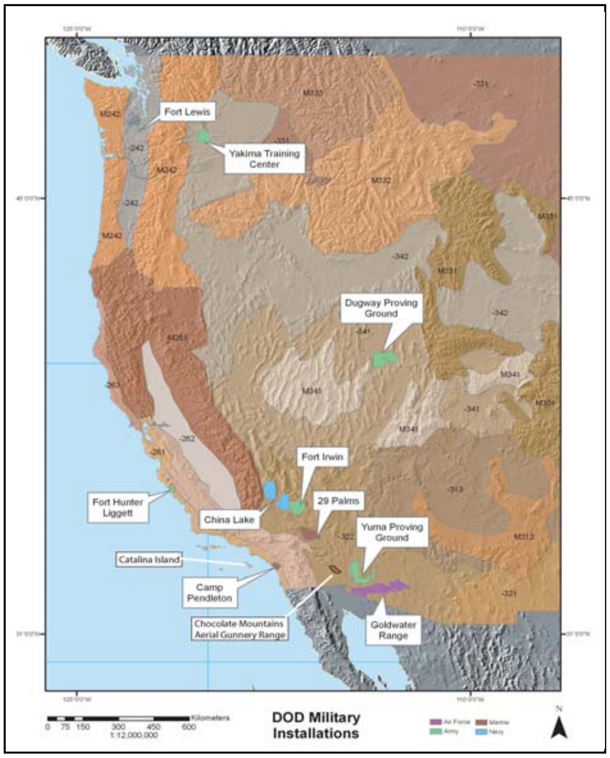


Fig. 1. Shaded relief map of the western United States superimposed on Bailey's ecoregions (1996) showing the locations of military installations in the ecoregions.

<u>Key to Pertinent Divisions and Provinces</u>

242 – Marine Division, Pacific Lowland Mixed Forest Province

261 – Mediterranean Division, California Coastal Chaparral Province

322 – Tropical-Subtropical Desert Division, American Semi-Desert Province

341 – Temperate Desert Division, Intermountain Semi-Desert and Desert Province

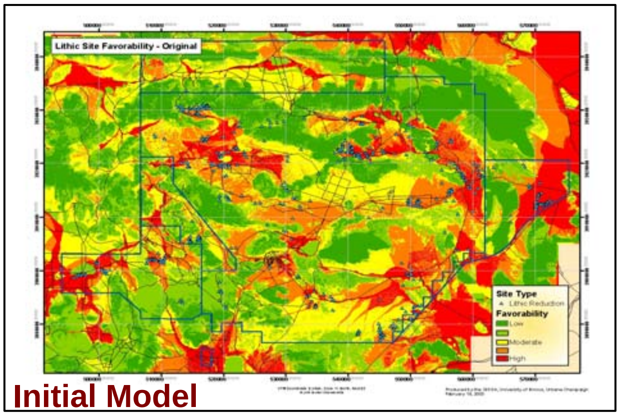
342 – Temperate Desert Division, Intermountain Semi-Desert Province

3.1 Archaeological predictive model

We are expanding and enhancing our landform-based archeological predictive model (McDonald et al., 2004a) to make it adaptable and applicable in a wider range of environmental settings. The model was initiated in the Mojave Desert at the U.S. Army National Training Center at Ft. Irwin in collaboration with archaeologists from the University of Illinois and the Construction Engineering Research Laboratory of the U.S. Army Corps of Engineers in Champaign, Illinois. After acquisition of a modest soil-geomorphic and cultural resources data set and development of a GIS-based model, the initial model met with good results (Fig. 2) (McDonald et al., 2004a) and has been applied during independent cultural resource surveys at the NTC (Grant et al., 2004; Peter et al., 2004). The approach employed involves working closely with installation cultural resources departments and conducting field campaigns to characterize the natural environment and geomorphic processes associated with known archeological sites. A matrix of geologic, soil, and geomorphic variables is used to categorize the complex desert landscape at known archeological sites to determine which components might prove to be most useful in development of the archaeological predictive model. The descriptors used in the matrix are based on defined geomorphic principles and are selected to limit overlap among topographic position, morphology, deposit, and/or surface age. Further evaluation of these variables will facilitate development of a short-list that will supply the greatest level of geomorphic information using the least number of descriptors possible. Moreover, the developed list of variables has potential for future use by field archaeologists to incorporate soil-geomorphic and geologic information during field collection of cultural resource data.

3.2 Geomorphic linkage with habitat

During visits to military installations, we have observed endangered species habitat concerns that could be managed or mitigated through scientific understanding of the long-term behavior of the geomorphic systems influencing habitats. For example, the endangered arroyo southwestern toad (*Bufo microscaphus californicus*) is found in riparian zones at Fort Hunter Liggett (U.S. Army Reserve) and Marine Corps Base Camp Pendleton (U.S. Marine Corps), and the Pacific pocket mouse (*Perognathus longimembris pacificus*) is found in coastal marine terrace settings at Camp Pendleton. In some instances disturbance in habitat has resulted in formation of new habitat, to which the species have taken advantage. This is a case where an apparent negative stressor results in a positive response. Working together with wildlife biologists and through field geomorphic research we can gain a deeper



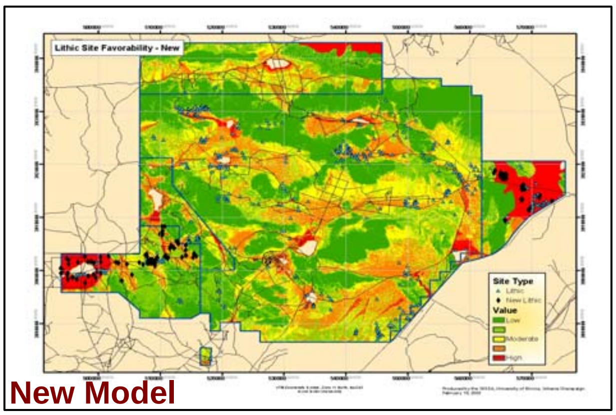


Fig. 2. Example of GIS-based model predicting favorability of lithic scatters. Top initial model is based primarily on environmental data; lower "new model" incorporated a very modest amount of geologic data, yet yielded large improvements in the predictive capability of the model. Incorporation of key geomorphic and soil data is expected to greatly improve model capabilities.

understanding of the long-term history of the landscape and how that history and geomorphic processes influence habitat structure. In turn, the knowledge of landscape history and predictable geomorphic processes provide wildlife biologists with tools to assess potential species response to disturbance as well as dynamic landscape response to extreme climate events. In the hot desert region, important endangered plant and animal species found on installations (e.g., NTC – U.S. Army National Training Center) include the milk vetch (*Astragalus)* and the endangered desert tortoise (*Gopherus agassizii*). These flora and fauna live in two contrasting habitats, both of which are well known and well documented. What are not known or documented are the soil-geomorphic controls on habitat and how disturbance of these environments might impact habitat. A better understanding of the natural soil-geomorphic associations of their habitat integrated with existing knowledge on life history and vegetation requirements for these species can complement TES management practices and lead to strengthening the status of these important flora and fauna.

3.3 Soil geomorphology and soil hydrology in support of controlling environmental degradation

To comply with mandated INRMPs (Integrated Natural Resources Management Plans), Integrated Training Area Management (ITAM) and related programs (e.g., RTLA, LRAM, TECOM) at DoD installations, managers are tasked with maintaining the condition of training areas, including providing a safe and realistic training environment as well as performing maintenance and rehabilitation on damaged lands. Important to performing proper maintenance and rehabilitation is the knowledge that distribution of soils across the landscape and their role in geomorphology are important in controlling behavior of surface water, its interactions with near and subsurface soil conditions, and its utilization by plants (e.g., McAuliffe and McDonald, 1995; McDonald et al., 1996; Smith et al., 1997; Hamerlynck et al., 2000; Bullard, 2005). DRI has been involved in landscape research activities at several DoD installations in the arid southwestern U.S. and coastal semiarid environments to investigate these issues and the role of soil-geomorphic and soil-hydrologic characteristics as they relate to military training activities and landscape dynamics (Bullard and McDonald, 2002; McDonald and Caldwell, 2003a, b, 2006; McDonald et al., 2004b). Throughout the past decade, DRI research has established relationships between landscape evolution and geomorphology, soil development, dust potential, and soil hydrology to better understand the physical characteristics of individual landscape components. For example, the nature and degree of soil-hydrologic responses to surface disturbance are shown to correspond to landscape age and soil characteristics (e.g., McDonald, 2003a, b; McDonald and Caldwell, 2003, 2006; Caldwell et al., 2006a, b), and portable wind tunnel experiments have shown that susceptibility and magnitude of dust emissions vary with landscape age and position (e.g., Sweeney et al., 2006, 2008). Results of these studies demonstrate the importance of the relationship among geomorphology, soils, landscape age, and disturbance characteristics. The next logical step is to integrate geomorphology, soils, hydrology, and dust into models that can be used to designate areas vulnerable to wind or water erosion or dust emission and anticipate those areas that could present potential safety concerns or sustainability issues related to training.

6. SUMMARY

LanDPro research supports scientific development of new methods and models to better understand (1) geomorphic controls on distribution of cultural resources

leading to advances in inventory surveys; (2) soil, hydrologic, and geomorphic controls on threatened and endangered species habitats leading to greater understanding of habitat structure and responses to disturbance; and (3) linkages between soil-geomorphology, soil-hydrology, and landscape evolution on distribution of dust in desert and semiarid environments as well as a better understanding of complex controls on erosion resulting from natural and human-induced disturbance on training lands.

Project results will benefit conservation and land management programs at installations selected for field studies as well as other installations where results may be applicable. Results from this project—including geomorphic mapping, analysis of landscape components, and predictive modeling for archeological sites—will support conservation and land management concerns such as Integrated Training Area Management (ITAM) program, TECOM/Range Training Area Management (RTAM) Division (Marine Corps), and the Army RTLA, Army Training in both arid and semiarid regions.

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